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KOMMISSIONEN FOR DANMARKS FISKERI- OG HAVUNDERSØGELSER

SERIE: PLANKTON · BIND V

NR. 3. POUL JESPERSEN: INVESTIGATIONS ON THE OCCURRENCE AND QUANTITY OF HOLOPLANKTON ANIMALS IN THE ISEFJORD, 1940—1943

KØBENHAVN
C. A. REITZELS FORLAG
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INVESTIGATIONS ON THE OCCURRENCE AND QUANTITY OF HOLOPLANKTON ANIMALS IN THE ISEFJORD, 1940–1943

BY

POUL JESPERSEN

WITH 11 TEXT-FIGURES

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I. Introduction.

The present report is based on plankton material collected in the years 1940—43 in the Isefjord, a fjord lying in the northern part of Zealand and extending from north to south. In this work only the holoplankton animals are dealt with[1]. The temporary zooplankton (larvae of bottom animals) will be described later by Gunnar Thorson and the phytoplankton by E. Steemann Nielsen in special reports. The last-mentioned will deal in more detail with the fjord itself and the prevailing hydrographical conditions and on these matters reference may be made to his report which will appear in the near future.

II. Material and methods.

The plankton collections for these investigations were made as follows in the various years.

In 1940 the collections were made partly by horizontal hauls with the silk net and partly by water-samples, at 3 stations in the fjord complex, namely:

St. I. Entrance to the Isefjord, 55°58′ N., 11°50.7′ E., depth 7.5 m.
St. II. Outer broad of the Isefjord. 55°53.7′ N., 11°49.4′ E.; depth 9.5 m.
St. III. Inner broad of Isefjord, 55°43′ N., 11°49′ E.; depth 7 m.

The position of the stations will be seen from the chart Fig. 1. The plankton hauls were made with a silk net (diameter 50 cm., silk No. 3), towed on the surface for 2 minutes. The water-samples, taken with a bucket of 8 litres capacity, were taken partly on the surface, partly at a depth of 6—8 m.; the water was filtered through a sieve, the bottom covered by a piece of No. 25 silk.

For the purpose of following the variations at a single locality in the quantity and composition of the plankton from year to year and at the different seasons, fairly regular collections were made monthly in the years 1941—43 at the station III in the inner broad of the Isefjord. These collections were made partly by means of two successive vertical hauls with a silk net (diameter 50 cm., silk No. 3) from a depth of 4—5 m. up to the surface, partly by taking water-samples (8 litres) at the surface and at a depth of 4—5 m. The water was filtered through silk No. 25. In 1941 water-samples were taken once or twice monthly in the period from March to December, whilst the vertical hauls with the silk net were only taken in the

[1] Holoplankton or permanent plankton refers to animals which pass their whole life-cycle up in the water, in contrast to the temporary plankton (meroplankton), which includes the planktonic eggs and larvae of bottom-animals (benthos) and swimming animals (nekton).

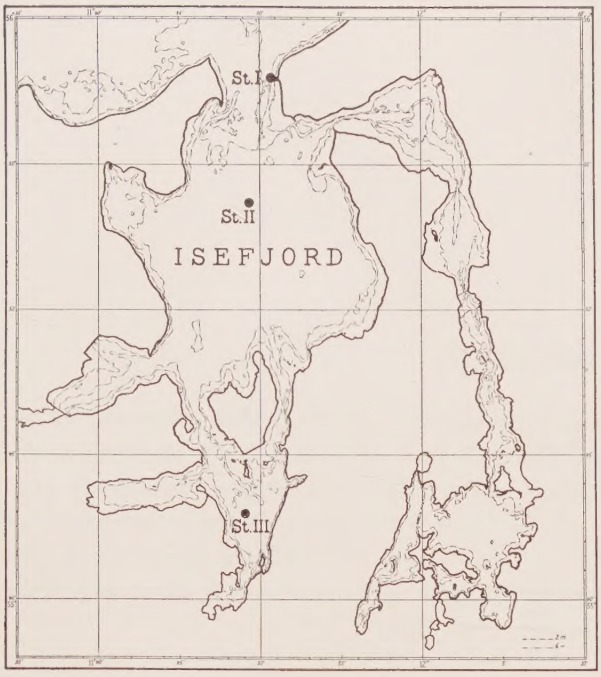

Fig. 1. Chart of the Isefjord showing the position of the three stations I—III.

last months of the year, from September to December. Owing to the ice conditions in 1942 the investigations could only begin in March-April; thereafter collections once to twice monthly were continued till the end of the year and on to August in 1943. They had to be discontinued in August 1943 as the Danish soldiers were then interned by the Germans; as the collections had been made at a sea-mine station of the Danish Navy, there was no possibility of continuing them.

The material collected in the horizontal hauls with the silk net were not subjected to a very close examination, as the method used did not give an exact expression of the quantitative occurrence of the different organisms. For this material therefore only an estimate was made, using the common frequencies cc, c, +, r and rr. In all other cases, whether vertical hauls with the silk net or water-samples, an exact enumeration of the different organisms was made. A single group is excepted, however, the coelenterates, partly owing to their extremely small numbers and partly because a certain determination of the species was impossible in the case of quite young individuals. Otherwise an exact determination to species has been made as far as possible, but this could not be done for a few groups such as the nauplii of copepods, harpacticids, quite young copepod stages etc., and these have been either taken altogether or referred to the species most abundant in the respective samples.

In the following the material from the 3 mentioned stations in the Isefjord in 1940 will first be considered and thereafter the material from the station in the inner broad of the Isefjord for the years 1941, 42 and 43.

III. Material from 3 stations in the Isefjord, 1940.

In the summer and autumn of 1940 plankton collections were made at 3 stations in the Isefjord. Their position has been indicated above and is shown on the chart Fig. 1. The collections, partly by silk net and partly by water-samples, were made on the following dates: 24, June, 1, August, 30, August and 15, October.

The net collections were made, as noted above, by towing the net on the surface for two minutes. As the material from these horizontal hauls cannot yield any trustworthy picture of the quantitative occurrence of the different organisms, no enumerations were made and only estimated frequencies are noted, as in Table 1.

These surface hauls show that the copepods are by far the most abundant at all stations. The genus *Acartia* is present in most hauls in by far the greatest number. There are 4 species,

Table 1. Relative frequency of various holoplankton animals collected with the silk net at the surface on 3 stations in the Isefjord 1940.

	St. I				St. II				St. III			
	24. VI	1. VIII	30. VIII	15. X	24. VI	I. VIII	30. VIII	15. X	24. VI	1. VIII	30. VIII	15. X
Calanus finmarchicus	..	..	rr	..	..	..	..	..	..	..	..	..
Paracalanus parvus	..	rr	cc	r	..	..	r	r	..	..	..	..
Pseudocalanus minutus	..	..	+	rr	..	..	..	..	..	..	..	..
Temora longicornis	rr	..	..	..	..	..	..	rr	..	..	..	..
Centropages hamatus	c	r	rr	rr	+	r	r	r	r	rr	r	r
Acartia longiremis	..	..	..	cc	..	..	..	rr	..	..	..	..
— discaudata	..	r	..	rr	..	c	+	+	c	c	cc	c
— bifilosa & tonsa	cc	+	+	r	c	c	c	c	+	cc	cc	+
Oithona similis	..	..	..	rr	..	..	..	r	..	..	..	rr
Evadne nordmanni	rr	..	r	..	..	..	rr	rr	..	..	..	..
Podon polyphemoides	..	rr	r	rr	r	rr	r	rr	r	rr	rr	rr
Sagitta setosa	..	r	..	rr	..	r	rr	..	..	..	..	rr
Oikopleura dioica	..	..	..	r	..	..	..	rr	..	..	..	..

Acartia bifilosa, *A. tonsa*, *A. discaudata* and *A. longiremis*. As it was not possible everywhere to distinguish between the first 2 species, they have been taken together in the table. It may be said in general, that *A. bifilosa* occurs in greatest numbers at the two outermost stations (I and II), whilst *A. tonsa* is dominant at the innermost (III), as also *A. discaudata*. All four *Acartia* species occur at the two outermost stations, but *A. longiremis* is absent at the innermost station. Among the other copepods it is worth noting, that two species, *Calanus finmarchicus* and *Pseudocalanus minutus*, are only present at the outermost station and that such species as *Centropages hamatus* and *Paracalanus parvus* are clearly on the decrease from the outermost to the innermost station. Other holoplankton animals like Cladocera, Appendicularia and Sagitta are only present in small quantities in the hauls with silk net. These samples, taken by means of such a coarse-meshed net, contain naturally only the larger plankton organisms; all nauplii and many copepodite stages as well as small adult copepods are thus not taken with this apparatus.

As mentioned above, along with the surface hauls water-samples were taken at the same time with a bucket holding 8 litres and the water was filtered through silk gauze No. 25. The samples were taken from two depths, surface and down to 6—8 m.; enumeration of the organisms in the water-samples has given the result shown in Table 2.

Among the copepods no separation has been made of the species of the genus *Acartia*, as it was not possible to identify the different copepodite stages. Nor has any attempt been made to separate the species of the Harpacticidae and nauplii.

As will be seen, the copepod nauplii, which were not taken at all in the silk net, are present in all water-samples and in very considerable numbers. A quantitative comparison of the nauplii taken in the different water-samples at the two depths is shown graphically in Fig. 2.

Table 2. Number of holoplankton animals per 8 litres water at 3 stations in the Isefjord 1940. The upper row shows the numbers at the surface, the lower those in 6—8 m.

	St. I				St. II				St. III			
	24. VI	1. VIII	30. VIII	15. X	24. VI	1. VIII	30. VIII	15. X	24. VI	1. VIII	30. VIII	15. X
Paracalanus parvus	..	3	28	5	..	..	7	..	..	..	..	..
	..	7	26	6	..	..	5	6	..	..	..	..
Pseudocalanus minutus	1	..	1	..	..	..	1	..	..	..	..	..
	..	24	2	1	..	..	..	..	..	..	..	..
Eurytemora hirundoides	..	..	..	..	..	..	..	..	..	3	..	..
	..	..	..	..	..	..	..	..	..	..	..	..
Centropages hamatus	20	5	..	..	52	..	2	1	7	..	1	..
	11	..	..	..	73	1	..	1	10	..	..	..
Acartia sp.	27	33	7	15	23	267	159	10	47	169	85	17
	37	85	3	29	34	88	130	24	68	285	214	21
Oithona similis	4	14	22	26	16	14	13	30	..	2	..	11
	51	11	26	47	107	2	10	62	3	1	2	17
Harpacticidae	1	1	..	..	1	..	2	1	1	1	1	3
	2	1	1	..	4	1	..	3	7	5	..	..
Copepod nauplii	19	73	12	43	145	143	95	82	208	420	202	93
	57	50	28	60	300	262	79	92	365	705	495	118
Evadne nordmanni	..	..	1	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..
Podon polyphemoides	..	1	..	..	4	6	18	2	16	1	2	4
	2	2	2	1	20	8	9	2	38	7	7	2
Sagitta setosa	..	..	..	..	..	1	1	..	..	..	..	..
	..	..	2	..	..	..	1	..	..	..	..	..
Oikopleura dioica	..	..	..	20	1	..	..	22	..	..	..	9
	..	..	..	15	3	..	1	35	..	..	..	5

It will at once be noticed, that the number rises greatly from the outermost (I) to the innermost station (III). At the last also it is clearly seen, that the largest quantities occur in the month of August, the smallest in the October sample. The numbers for the nauplii are almost everywhere greater in the deeper layers than at the surface.

For comparison with the quantities of nauplii Fig. 3 shows the total number of adult copepods and copepodite stages in all samples.

Here it is likewise obvious, that the smallest numbers are found at the outermost station, whilst there is no essential difference in the quantities at the two innermost stations. Just as for the nauplii there is a distinct decrease in the quantities of adult copepods and copepodite stages in October, specially evi-

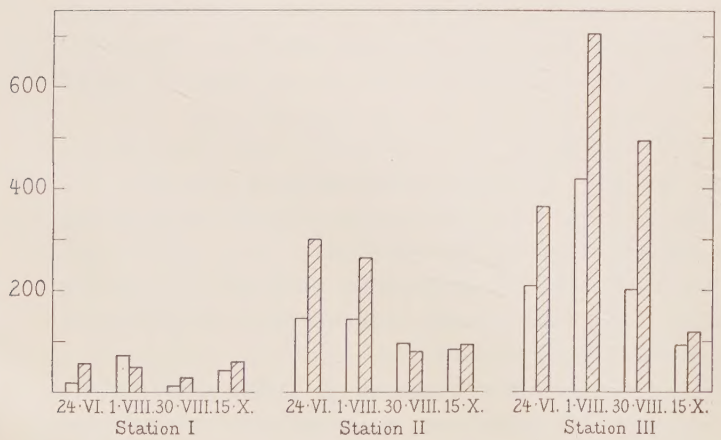

Fig. 2. Number of copepod nauplii at the surface (white column) and at 6—8 m. (shaded column) at 3 stations in the Isefjord 1940.

dent at St. III. At this station also there is a surprising agreement between the relative numbers of nauplii and the relative numbers of adult copepods and copepodite stages, not only at the different periods when the collections were made, but also at the two depths. A comparison of the graphs in Figs. 2 and 3 for the numbers at St. III clearly shows this agreement, though it should be noted, that Fig. 3 is drawn on a larger scale than Fig. 2. The nauplii are most numerous at the innermost station (III) not only in absolute numbers, but also in relation to the numbers of adult copepods + copepodite stages. This can be seen from the following summary.

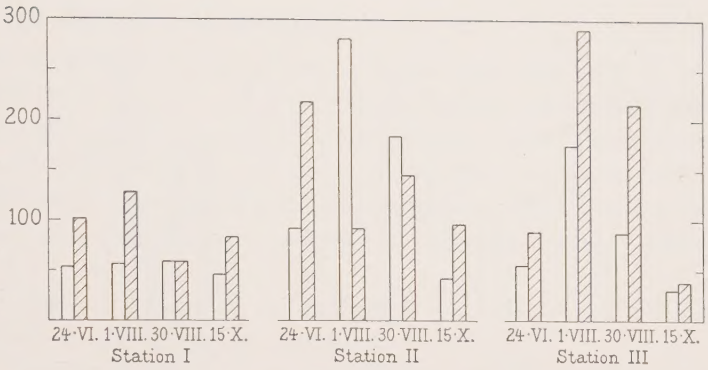

Fig. 3. Total number of adult copepods and copepodite stages at the surface (white columns) and at 6—8 m. (shaded column) at 3 stations in the Isefjord 1940.

Table 3. Number of nauplii in relation to the total number of adult copepods + copepodite stages at 3 stations in the Isefjord 1940.

Date	St. I.	St. II.	St. III.
24th June	33.0 %	58.9 %	80.0 %
1st August	40.1 %	52.1 %	70.7 %
30th August	25.6 %	34.6 %	69.7 %
15th October	44.4 %	55.8 %	75.4 %
Mean	35.8 %	50.3 %	73.9 %

Looking more closely at Table 2 (p. 6) it is worth noting, that the copepods *Paracalanus parvus* and *Pseudocalanus minutus* do not occur at St. III, yet at the two other stations, as also that *Centropages hamatus* only occurs in relative small numbers at the innermost station (III). In these conditions there is good agreement with the quantities found in the samples collected with the net (cf. Table 1, p. 5).

Of other organisms it need only be noted, that at both depths *Podon* occurs in considerably greater numbers at the two innermost stations (II and III) than at the outermost; also that *Oikopleura dioica*, which occurs in quantities only in the samples from October, is clearly most abundant at the two outermost stations (I and II).

IV. Material from St. III in the inner broad of the Isefjord 1941—43.

At this station hauls with the silk net and water-samples were taken in the 3 years. The results from the two methods may be kept separate, beginning with the samples collected by silk net.

1. Material collected by silk net.

The net used was 50 cm. in diameter (silk No. 3) and the collections were made in two successive vertical hauls from 4—5 m. up to the surface. The different organisms from these hauls were counted, identification of the species being made where this could be done. The collections were made once to twice monthly from September to December 1941 and from April 1942 to August 1943. No hauls were made in 1942 before April owing to the fjord being covered with ice the greater part of the winter.

Table 4. Number of holoplankton animals in vertical hauls with the silk net at St. III in the inner broad of the Isefjord 1941—43.

	1941					1942							1943									
	30. IX	14. X	28. X	19. XI	10. XII	28. IV	19. V	21. VII	25. VIII	29. IX	27. XI	18. XII	20. I	12. II	5. III	26. III	16. IV	7. V	28. V	18. VI	8. VII	30. VII	20. VIII
Paracalanus parvus	165	280	117	315	125	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Pseudocalanus minutus	..	..	..	30	20	15	18	..	..	..	..	..	..	..	4	..	..	..	..	..	..	..	..
Temora longicornis	5	..	2	..	5	..	..	..	4	10	8	8	6	..	2	..	..	..	..	..	..	..	..
Eurytemora hirundoides	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	2	..	..	..	..	..	..	..
Centropages hamatus	25	49	23	55	55	19	20	38	122	26	30	16	68	..	14	..	22	16	8	..	..	4	4
Acartia longiremis	..	..	..	..	5	11	8	..	..	..	..	..	32	..	2	..	..	4	..	..	..	..	..
— discaudata	670	77	23	10	20	..	..	6	9	4	..	..	..	..	..	..	..	12	..	2	..	58	8
— bifilosa & tonsa	485	441	59	400	220	18	15	62	12	2	8	6	46	..	54	6	62	82	2	8	..	126	24
Oithona similis	75	147	41	210	580	14	6	28	3	..	10	10	22	4	2	2	..	..	..	..	..	..	..
Harpacticidae	..	..	..	..	..	..	..	6	4	10	..	2	..	..	2	4	2	6	4	2	2	10	10
Copepod nauplii	..	14	..	..	10	..	..	..	..	..	..	..	..	2	..	..	2	..	..	..	..	..	24
Evadne nordmanni	185	462	86	..	..	..	..	344	90	2	..	..	..	..	..	..	..	..	..	..	..	..	..
Podon polyphemoides	615	252	4	..	..	..	..	330	125	6	..	..	..	..	..	..	..	8	12	10	4	192	2
Sagitta setosa	25	84	3	205	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Oikopleura dioica	560	945	8	..	..	..	..	158	211	2	..	..	..	..	..	..	..	..	..	..	..	6	..
Total no. of animals	2810	2751	366	1225	1040	78	67	972	580	62	56	42	174	6	80	14	88	128	26	22	6	396	72

Table 4 shows the number of the different organisms in all the vertical hauls, and it will be noticed at once, that the number of holoplankton animals was much greater at the end of 1941 than in 1942 and 1943. This becomes specially clear from the following comparison, where the monthly average for the total number of holoplankton organisms per haul is indicated.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.
1941	..	..	..	..	..	..	..	..	2810	1558	1225	1040
1942	..	..	..	78	67	..	972	580	62	..	56	42
1943	174	6	47	88	77	22	201	72	..	..	..	..

Comparison of the quantities in Nov. and Dec., shows that in 1941 there were about 23 times as many holoplankton animals in the water as in the respective months of 1942.

The monthly averages for the four principal groups: Copepoda, Cladocera, *Sagitta* and *Oikopleura* are shown graphically in Fig. 4.

As will be seen, the numbers for all groups are much greater in Sept.—Dec. 1941 than in the corresponding 4 months of 1942. Comparing the averages for the months July—August in 1942 and 1943 we see further, that the numbers in 1943 are on the whole considerably lower than in 1942. For the copepods the difference in the summers of 1942 and 1943 is not exceedingly great, but in July—Aug. 1943 both *Cladocera* and *Oikopleura* appeared in much smaller numbers than in the corresponding months of 1942. In neither of the years 1942 and 1943 was *Sagitta* present in the plankton material, which is all the more remarkable as *Sagitta* was fairly frequent in the samples from Sept.—Nov. in 1941.

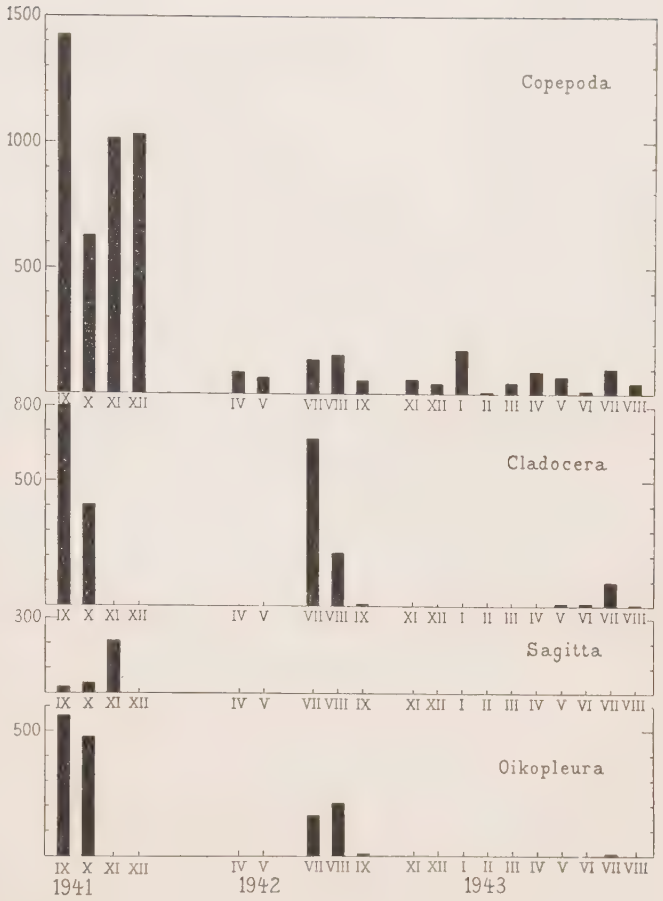

Fig. 4. The monthly averages for the copepods, Cladocera, *Sagitta* and *Oikopleura* taken in silk net at St. III in the inner broad of the Isefjord 1941—43.

Considering the occurrence of the various copepod species, represented in Table 4, it is of interest to note, that *Acartia discaudata* as well as *A. bifilosa* + *tonsa* appeared in large quantities in the last 4 months of 1941, but in relatively small numbers in the two following years. Further, it appears from the Table, that *Pseudocalanus minutus* and *Paracalanus parvus*, quite numerous in the material from Sept.—Dec. 1941, are not at all present in the samples from the corresponding months of 1942 and do not occur either in the material from the summers 1942 and 43. *Oithona similis*, likewise frequent in Sept.—Dec. 1941, decreased greatly in quantity in the samples from the corresponding months of 1942 and were not at all present in the material from the summer of 1943. As exceedingly few copepod nauplii were taken in the relatively coarse-meshed net, no importance can be ascribed to the few specimens obtained by the net. The two species of Cladocera, *Evadne nordmanni* and *Podon polyphemoides*, both with a marked seasonal occurrence, seem likewise to be decreasing evenly in numbers from 1941 to 1943. Thus, *Evadne* was numerous in Sept.—Oct. 1941 and in July—Aug. 1942, but was entirely absent in the samples from the summer of 1943; for *Podon* also there is a decided decrease in the numbers. This is even more apparent for *Sagitta setosa* and *Oikopleura dioica*, as can be seen very clearly from Fig. 4.

The results of the net collections thus make it evident, that the great majority of the holoplankton animals were in much greater numbers in the last third of 1941 (Sept.—Dec.) than in the corresponding months of 1942. It is also evident, that considerably larger quantities

of these were present in the summer of 1942 on the whole, than in the following summer of 1943. Thus, there seems to have been a tendency for the quantities of plankton to decrease somewhat evenly from 1941 to 1943.

2. Material collected in water-samples.

In the years 1941—43 along with the net samples collection of water-samples of 8 litres was made at St. III in the inner broad of the Isefjord at two different depths, at the surface and at 4—5 m. The organisms in these samples were counted and the species determined as far as possible. Whilst the net collections only began in September 1941, the taking of the water-samples had already commenced in March of that year.

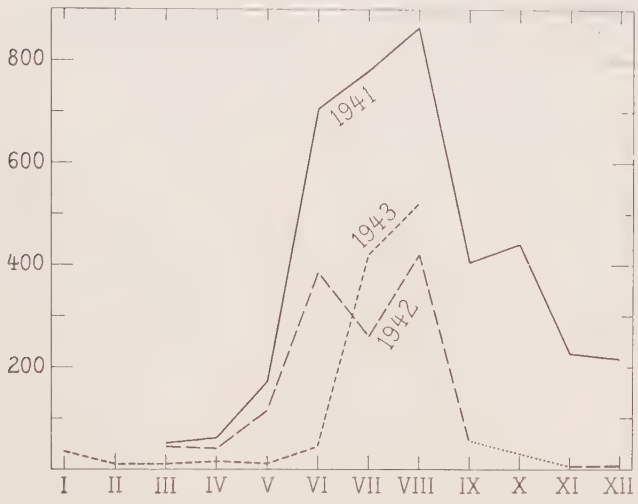

Fig. 5. The monthly average quantity of holoplankton animals in 8 litres water in 1941—43, calculated as the mean of the numbers at the surface and in 4—5 m. depth.

To obtain some idea of the variations in total number of holoplankton animals at the different seasons and in the different years a calculation has been made of the monthly averages in the years 1941—43 (Fig. 5). To simplify the presentation curves have not been given for both the surface and depth averages, but the curves given show for each month an average of the quantities of both together. It will be seen from Fig. 5, that the quantity of plankton, fairly small in winter, rises quickly from May to June in 1941 and 1942, where in 1943 the increase only takes place from June to July. The maximum occurs in the months June (July) to August; thereafter, at least in the two years (1941 and 1942) there is a very great decrease in the quantities from August to September. In 1943 the collections ended in August.

Comparing the quantities in the 3 years when investigations were made, we see at once that the total quantity of organisms in all the months of collection was quite considerably larger in 1941 than in the two following years. As collections were made in all 3 years in the period from March to August this part of the year is best suited for the comparison. From March to June there is a considerably smaller number of organisms in 1942 than in 1941 and again many fewer in 1943 than in 1942, thus a steady decrease in the 3 years. In the months of July and August again by far the largest quantities were found in 1941, but the quantities in the same months seem to have been smaller in 1942 than in 1943. Both in 1941 and 1942 there is a very distinct and parallel decrease in the numbers from August to September, but the monthly numbers are quite considerably larger in 1941 than in 1942. This appears very distinctly on comparing the quantities for Nov. and Dec. In 1941 the numbers for Nov.—Dec. were respectively 225 and 216, in 1942 just 7 and 8, thus almost 30 times as many organisms in 1941 as in 1942. This agrees very well with the result from the silk net collections, the latter showing for Nov.—Dec. 1941 almost 23 times as many holoplankton organisms in the water as in the corresponding months of 1942 (Table 4, p. 8).

Turning now to the quantities of the different animals we may first consider the numbers of the copepods excluding the nauplii, i. e. total number of adult copepods plus the copepodite stages (Fig. 6).

In the years 1941 and 1942 we have practically the same quantities in the period from March to August, as shown by the two curves which run almost parallel to one another. From Sept. to Dec. however there is a great difference in the quantities in the two years, 1941 having

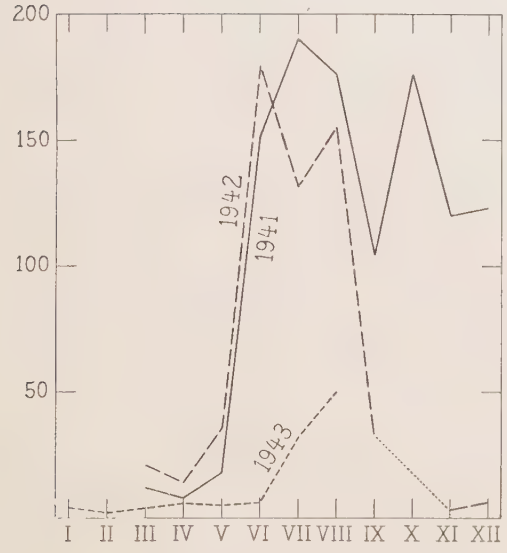

Fig. 6. Monthly averages of adult copepods and copepodite stages in 8 litres of water, 1941—43, calculated as mean of the numbers at the surface and in 4—5 m.

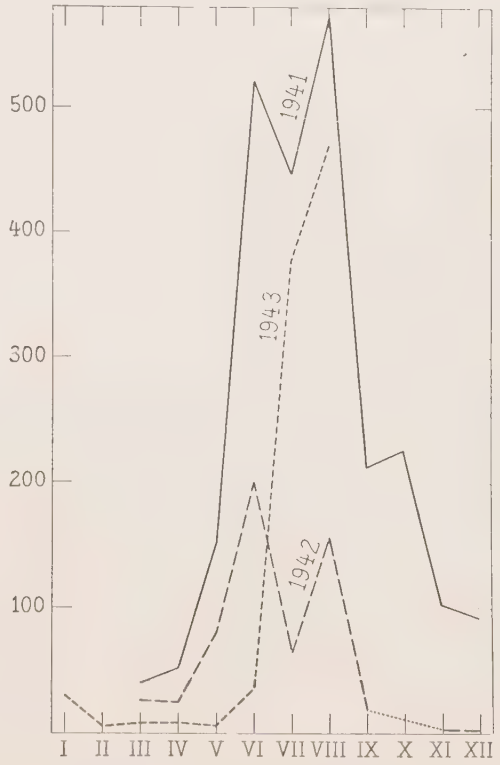

Fig. 7. Monthly average numbers of copepod nauplii in 8 litres water in 1941—43, calculated as mean of the numbers at the surface and in 4—5 m.

far larger numbers than 1942. For the latter certainly we have no collections from October, but in Sept. 1941 the average was 104 against 33 in Sept. 1942, and in Nov. and Dec. in the two years respectively 120—123 and 3—6 specimens. In 1943 the monthly averages were very small right from January to June, then a rise followed in July—August, but in neither of these months did the averages come anywhere near the quantities in the corresponding months of 1941 and 1942.

Comparing now the monthly averages for the copepod nauplii in the 3 years we obtain quite a different picture (Fig. 7).

In the summer months of 1941, from June to August, there are very large numbers of nauplii, far exceeding the numbers in the summer of 1942, even though the latter had also a maximum at the same time of year. In the winter of 1942—43 there were very small quantities of nauplii, also in the spring of 1943, but in June to July 1943 there was a very sharp rise in

the number, to the extent that in July and August 1943 we had almost equally large quantities of nauplii as in the corresponding months of 1941. Whilst the sudden rise in numbers of nauplii occurred in the period from May to June in 1941, in 1943 it only came a month later, namely from June to July. The summer of 1941 thus yielded strikingly large quantities of both adult copepods + copepodite stages and of nauplii. On the other hand, in the summer of 1942, when the quantities of copepods were just as great as in the preceding year, the numbers of nauplii were comparatively small; whilst in the summer of 1943 with relatively few adult copepod + copepodite stages we had quite a considerable number of nauplii. It appears from this, that only in 1941 was there a certain relation between the number of copepods + copepodite stages and the number of nauplii, whereas in 1942 and 1943 there seems to be no agreement in this respect.

Among the different copepods there are some which appear in such small numbers that they contribute very little to the total. These are to some extent seasonal forms. Thus *Paracalanus parvus* occurred in largest quantities in the second half of the year, *Pseudocalanus minutus* mainly in the period March to May and *Centropages hamatus* especially in the summer, from May to August. In the case of *Paracalanus* it is very remarkable that it occurred in fairly large numbers in Oct.—Dec. 1941 but not at all in the corresponding months of 1942.

Tables 5—6. Number of organisms in 8 litres water at St. III in the inner broad of the Isefjord 1941—43. Upper row: numbers at the surface; lower row: numbers in 4—5 m.

Table 5.

	1941																	
	13. III	28. III	9. IV	25. IV	8. V	29. V	12. VI	25. VI	16. VII	30. VII	14. VIII	27. VIII	11. IX	30. IX	14. X	28. X	19. XI	10. XII
Paracalanus parvus	..	..	..	..	..	..	..	..	..	..	15	..	..	..	19	7	18	24
	..	..	..	..	..	..	..	..	..	..	15	..	..	..	9	27	32	32
Pseudocalanus minutus ..	..	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	3	21	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Centropages hamatus	..	..	..	..	1	..	2	7	14	2	..	..	..	..	..	..	..	2
	..	..	..	..	..	..	3	28	21	3	..	..	..	..	1	2	1	3
Acartia sp.....	..	..	1	2	1	12	30	110	81	38	195	20	45	33	69	8	2	5
	..	..	6	1	9	23	30	361	180	82	145	10	10	81	92	17	9	11
Oithona similis	..	..	2	5	8	8	6	..	34	22	85	40	15	93	164	43	26	79
	2	2	1	5	2	4	15	3	147	114	115	60	40	96	162	87	150	91
Harpacticidae	..	5	..	1	..	1	5	1	2	1	10	5	..	3	1	..	..	..
	4	11	2	2	..	2	2	10	12	11	10	..	..	2	..	2	1	..
Copepod nauplii	19	32	27	45	145	185	458	305	452	457	870	280	235	91	325	112	25	39
	5	107	81	57	86	199	635	690	576	301	700	440	420	107	335	140	181	148
Evadne nordmanni	..	..	..	..	..	..	..	..	1	..	..	5	..	5	3	..	..	..
	..	..	..	..	..	..	..	..	5	..	..	..	..	2	7	..	..	..
Podon polyphemoides ...	..	..	..	..	..	..	60	4	..	1	15	65	20	7	4	..	..	..
	..	..	..	..	..	..	66	2	..	..	5	30	..	26	..	1	..	..
Sagitta setosa	..	..	..	..	..	..	..	..	..	..	10	5	5	..	1	..	1	..
	..	..	..	..	..	..	..	..	..	..	5	5	10	..	1	..	2	..
Oikopleura dioica	..	..	..	..	..	..	..	..	106	107	60	100	60	55	56	1	..	..
	..	..	..	..	..	..	..	..	186	172	70	100	120	49	82	1	1	..

Table 6.

	1942									1943										
	25. III	28. IV	19. V	16. VI	21. VII	25. VIII	29. IX	27. XI	18. XII	20. I	12. II	5. III	26. III	16. IV	7. V	28. V	18. VI	8. VII	30. VII	20. VIII
Paracalanus parvus	..	..	..	2	4	6	2	..	..	..	..	..	..	..	..	..	..	5	1	..
	..	..	..	26	2	6	..	..	..	..	..	..	..	..	..	..	..	1	..	..
Pseudocalanus minutus ..	3	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	4	1	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
Temora longicornis.....	..	..	..	..	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Centropages hamatus....	..	..	..	5	..	10	5	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	61	..	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Acartia sp.....	14	2	27	2	10	15	6	1	1	4	1	2	1	5	4	1	3	50	11	34
	..	8	14	58	7	18	3	1	5	..	1	2	..	4	..	..	..	7	10	54
Oithona similis	5	5	16	48	114	57	10	3	2	..	2	..	..	2	1	..	1	..	..	..
	21	5	11	144	118	183	12	..	5	3	..	2	..	..	..	..	..	1	..	..
Harpacticidae	..	3	1	5	6	5	5	..	..	..	..	5	1	1	..	..	2	34	12	5
	..	1	2	8	2	5	25	3	..	..	..	1	1	1	2	11	6	10	7	7
Copepod nauplii	41	16	93	268	96	162	19	4	..	36	8	10	4	10	7	6	40	520	535	415
	12	35	69	132	32	151	17	3	5	28	6	9	11	8	6	12	34	114	345	526
Evadne nordmanni	..	..	1	1	4	1	2	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	2	..	4	..	..	..	..	..	..	..	..	..	..	..	..	..	..
Podon polyphemoides ...	..	..	..	4	12	16	..	..	..	..	..	..	..	..	..	..	2	9	2	..
	..	..	..	..	14	20	3	..	..	..	..	..	..	..	..	..	« 2	1	1	..
Oikopleura dioica	..	..	..	..	52	82	..	..	..	..	..	..	..	..	..	..	..	..	..	..
	..	..	..	..	48	94	..	..	..	..	..	..	..	..	..	..	..	..	..	..

A considerable number of quite young specimens of the genus *Acartia* occurred in the different water-samples, but it was not possible to determine the species with certainty and no attempt therefore has been made to give a quantitative expression for the occurrence of the different species. In Fig. 8 uppermost curves are given for the monthly average numbers of the genus *Acartia* for each year 1941—43. It was only in the summer of 1941 that any considerable quantities occurred, especially in the period June to August, after which they decreased evenly towards the end of the year. Both in 1942 and 43 there were relatively small numbers of these copepods.

By comparison *Oithona similis* shows quite a different picture (Fig. 8 below); its numbers vary even more in the different years. In 1941 there was a sharp rise in the quantity from June to July, and the large number remains almost unchanged till the end of the year. By contrast 1942 shows a marked rise already in the period from May to June, thus a month earlier than in 1941; to counterbalance this

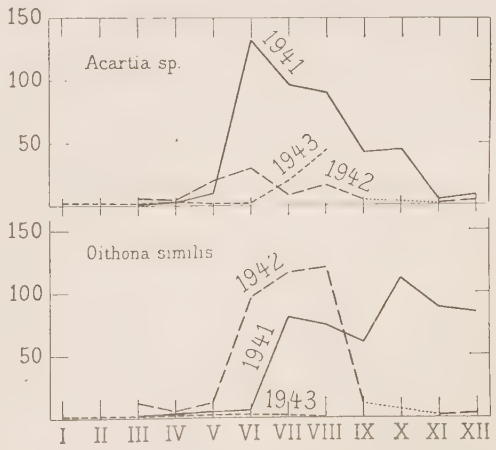

Fig. 8. Monthly average numbers of the genus *Acartia* and *Oithona similis* in 8 litres water in 1941—43, calculated as mean of the numbers at the surface and in 4—5 m.

the quantities greatly decrease already in the period from August to September. In Nov. and Dec. 1942 we have remarkably small quantities of *Oithona similis* by comparison with the corresponding months of 1941. In Nov. and Dec. 1941 the numbers were 88 and 85 respectively against only 1 and 3 in the same months of 1942. The 1943 collections are very remarkable in that the species occurs in exceedingly small numbers in all the months when observations were made (January—August); in the samples from July and August it is practically absent (monthly average 1—2 specimens). How extraordinary this is can be seen from the fact, that in the corresponding months of both 1941 and 1942 we found quite considerable quantities (monthly averages between 70 and 120 specimens).

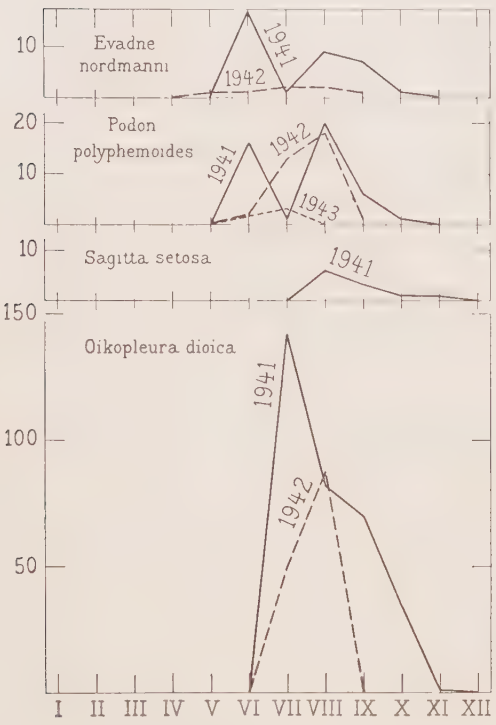

Fig. 9. The monthly average numbers of *Evadne nordmanni*, *Podon polyphemoides*, *Sagitta setosa* and *Oikopleura dioica* in 8 litres water in 1941—43, calculated as the mean of the numbers at the surface and in 4—5 m.

In the occurrence of the cladocerans there is also quite considerable differences in the three years. Only two species have been observed with certainty: *Evadne nordmanni* and *Podon polyphemoides*. Fig. 9 shows that *Evadne*, distinctly a summer form, occurred in 1941 in relatively large numbers in the period from June to October; in 1942 the numbers were considerably smaller and in 1943 it did not appear at all in the water-samples. The 1941 curve shows two peaks well-marked, with maximum occurrence in June and Aug.—Sept.; *Podon polyphemoides* shows something similar. In the case of the latter also fairly large quantities were taken in the water-samples in the summers of 1941 and 1942, whereas in 1943 (till August) the numbers were comparatively speaking much smaller.

The genus *Sagitta* only occurred in very small numbers in the water-samples; so far as a determination was possible the species was *Sagitta setosa*. As can be seen from the curve Fig. 9 small numbers of *Sagitta* (on an average 1—6 specimens per 8 litres) were taken in 1941 in the months Aug.—Nov., but neither in 1942, when collections were made in the same months, nor in 1943, when the investigations continued till August, were any *Sagitta* found in the water-samples. This is in full agreement with the results from the plankton samples collected with the silk net (Fig. 4, p. 9).

With regard lastly to the appendicularian *Oikopleura dioica* the peculiar thing is (see curves Fig. 9), that it occurs in considerable quantities both in 1941 and 1942 (maximal occurrence in respectively July and August) but not at all in the summer of 1943 (up to and including August). Comparison of the occurrences in 1941 and 1942 shows further, that in 1941 it appeared in the samples from July to November (though in diminishing numbers in the last-mentioned month), whereas in 1942 it was only found in the months of July and August, in both however in fairly considerable quantities.

V. Discussion of the results.

It is apparent from the above account, that quite considerable variations occurred in the quantitative occurrence of different holoplankton animals during the three years 1941—43, when investigations were made at St. III in the inner broad of the Isefjord. The two different methods of collection, vertical hauls with the silk net and water-samples, naturally give somewhat different results. Apart from this, the investigations give on the whole certain general features in the variation of the different plankton organisms. As the water-samples were collected the more regularly and contain various small plankton animals not taken by the silk nets, we may restrict our attention to the material resulting from an analysis of the water-samples.

In the following summary of the relative occurrence of various groups of zooplankton in the summer (chiefly May to September) during the 3 years of the investigations + indicates occurrence in large or relatively large numbers, ÷ that the organisms occur in relatively small quantities and 0 that they were not at all present in the water-samples from the year noted.

	1941	1942	1943
Copepoda excl. nauplii	+	+	÷
Copepod nauplii	+	÷	+
Acartia	+	÷	÷
Oithona	+	+	÷
Evadne	+	÷	0
Podon	+	+	÷
Oikopleura	+	+	0
Sagitta	+	0	0

Even though this summary is based on a pure estimate, it is quite evident that in 1941 all groups of organisms occur in relatively large quantities, in 1942 on the whole in smaller quantities and in 1943 quite obviously in still smaller quantities. There is, however, one exception to this steady quantitative decrease, the copepod nauplii; in 1943 these were present in considerably greater numbers than in 1942. As the war brought the collections to an end in the month of August 1943, it was not possible to determine, whether the large numbers of nauplii in the summer of 1943 had led to an increase in the numbers of adult copepods during the rest of the year.

As the winter of 1941—42, like the two previous winters, was unusually severe and the fjord was covered by thick ice for several months, the decreasing quantities of plankton might seemingly be ascribed to the hard winters, but the winter of 1942—43 was fairly mild without much ice on the fjord, so that this cannot be the explanation of the generally small numbers of plankton in the summer of 1943.

We may now consider the hydrographical conditions at St. III in the inner broad of the Isefjord during the years 1941—43. Fig. 10 shows the monthly surface temperatures in 1941—43, though data are lacking for the months of January and February in the first two years, 1941 and 1942, owing to the fjord being covered by ice. In these two months, however, the temperature has been below freezing point, whereas the mean monthly temperature for January 1943 was 0.2° and for February 2.7°. In March 1943 it was already up to 4.1° where in March 1941 and 1942 it had been only 0.6° and 1.3° respectively.

Following the temperature curves to the later months of the year we see that they agree in all essentials, but the mean temperature in July 1941 was remarkably high, 22.0° against 18.2° and 18.5° in the same month of 1942 and 1943. It does not seem possible therefore, to

find in the temperature conditions any explanation for the decreasing quantities of plankton from 1941 to 1943.

The mean monthly values for the surface salinity are shown in Fig. 11 and in these again we can see no reasonable explanation of the variations in the quantity of holoplankton animals[1].

For each of the 3 years there is the common feature, that the salinity greatly decreases in the course of the summer, in the period from April—May to Aug.—Sept., then rises again

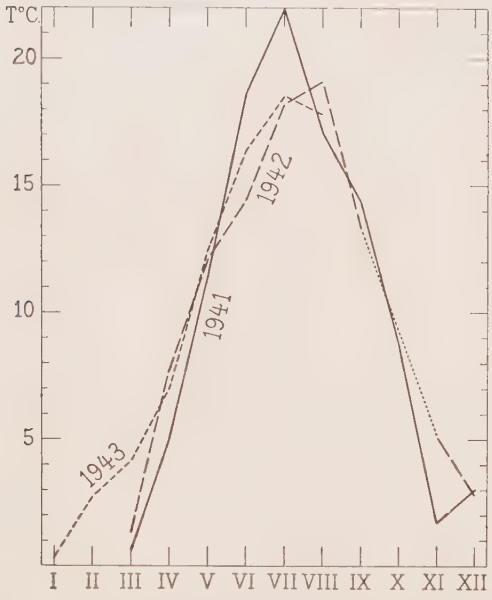

Fig. 10. Mean monthly temperatures of the surface water at St. III in the inner broad of the Isefjord 1941—43.

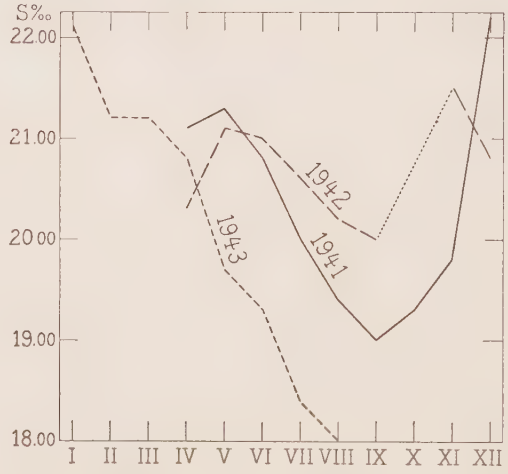

Fig. 11. Monthly salinity in the surface water at St. III in the inner broad of the Isefjord 1941—43.

in the autumn and winter. Whilst the two curves for 1941 and 1942 have essentially the same course, though in the autumn of 1942 (Sept.) the minimum salinity was about 1 ‰ higher than in 1941, it is quite evident that the salinity in the summer of 1943 was remarkably low. The mean salinity for August in the 3 years was: 1941: 19.40 ‰, 1942: 20.20 ‰ and 1943: 18.00 ‰. The small amount of plankton in 1943 might possibly be connected with the low salinity in the summer of that year, but in other years there is no corresponding relation with the salinities, so that no weight can be attached to this explanation.

On the whole then it seems evident, that the variations in the quantity of plankton cannot be related to the variations in the hydrographical conditions.

[1] The salinity for March 1941 is not included in Fig. 11; owing to the melting of the ice it was extremely low, 18.70 ‰.

Dansk Resumé.

I årene 1940—43 blev der foretaget indsamlinger af plankton i Isefjorden. Nærværende arbejde omhandler udelukkende de planktondyr, der tilbringer hele deres liv i svævende tilstand, medens larverne af bunddyr senere vil blive gjort til genstand for særlig behandling. Materialet omfatter dels planktonprøver, der i 1940 er indsamlet på 3 stationer i Isefjord (se kortet fig. 1, hvor stationerne er mærket I, II og III), dels prøver indsamlet på den inderste station (st. III) i årene 1941—43. Indsamlingerne i 1940 blev foretaget ved horisontaltræk med silkepose (diameter 50 cm, silke nr. 3) i 2 minutter i overfladen samt ved vandprøver à 8 liter i overfladen og i en dybde af 6—8 m. De i årene 1941—43 udførte indsamlinger på st. III skete dels ved to umiddelbart efter hinanden følgende vertikaltræk med silkepose fra 4—5 m dybde til overflade, dels ved optagning af vandprøver à 8 liter i overflade samt i en dybde af 4—5 m.

I tabel 1 gives en oversigt over den relative hyppighed af planktondyr i de forskellige prøver indsamlet med silkepose i overfladen på de 3 stationer i 1940. Copepoderne er langt dominerende i antal, men de forskellige arter optræder i meget forskellig mængde på de 3 stationer. Nogle arter er talrigst på de ydre, andre på den inderste station. Vandprøver fra samme stationer (fig. 2) viser, at de yngste stadier af copepoder — nauplier — forekommer i størst mængde på den inderste station (hvid søjle viser antallene i overflade, skraveret søjle antallene i 6—8 m dybde). Ganske det samme, men i mindre udtalt grad, gælder det for den samlede mængde af ungdomsstadier af copepoder (copepoditstadier) og voksne copepoder (fig. 3), idet vi for disse har de største antal på de to inderste stationer (st. II og III).

Formålet med de i årene 1941—43 på st. III foretagne indsamlinger er på en bestemt lokalitet at følge variationerne i planktonets mængde og sammensætning fra år til år og på de forskellige årstider. De med silkepose foretagne indsamlinger viser, at den samlede mængde af planktondyr i de sidste 4 måneder af 1941 var mange gange (gennemsnitlig ca. 23 gange) så stor som i det tilsvarende tidsrum i 1942. Mængden af de vigtigste organismer er afsat grafisk i fig. 4, hvoraf det endvidere ses, at antallene i 1943 gennemgående var betydeligt mindre i 1942. De foreliggende resultater synes derfor at godtgøre, at planktonmængden i alt væsentligt har været nogenlunde jævnt aftagende i årene fra 1941 til 1943.

De indsamlingerne med net kun giver et indtryk af de relativt store planktondyrs forekomst, er de suppleret med undersøgelse af vandprøver. De månedlige gennemsnitsantal af samtlige planktondyr i vandprøverne er afsat i fig. 5. Man vil bemærke, at planktondyrenes maximalforekomst findes om sommeren i månederne juni—august, men en sammenligning mellem kurverne for de enkelte år godtgør endvidere, at der i 1942 var ganske betydeligt færre individer end i 1941, hvorimod der i de to sommermåneder juli—august 1943 var omtrent samme antal som i 1942. Når forskellen i disse sommermåneder er så ringe, skyldes det især, at der i 1943 var betydeligt flere nauplier end i 1942, hvad der fremgår af fig. 7, der viser mængden af nauplier i de tre år. Ser man derimod på mængdeforekomsten af andre organismer,

viser der sig så godt som overalt en tydelig aftagen i mængderne fra 1941 til 1943. Medens antallet af voksne copepoder og copepoditstadier var omtrent lige store i sommeren 1941 og 1942 var antallet meget ringe i 1943 (fig. 6). Både for copepodslægten *Acartia* og arten *Oithona similis* (fig. 8) gælder det, at mængden var ganske betydeligt mindre i 1943 end i de to foregående år og noget tilsvarende er tilfældet for andre planktonorganismer som cladocerer, *Sagitta* og *Oikopleura* (fig. 9), der alle viser yderst ringe antal i 1943 i sammenligning med de to foregående år. Som allerede anført, viser nauplierne et noget andet billede (se fig. 7), idet vi ganske vist i sommeren 1942 havde et langt færre antal end i 1941, men i sommeren (juli—august) 1943 atter havde en ganske betydelig stigning i antallet, så det næsten kom op på tilsvarende mængder som i 1941. Da indsamlingerne på grund af krigsforholdene måtte indstilles i august 1943, har det ikke været muligt at konstatere, om den store mængde nauplier i sommeren 1943 har bevirket en tiltagen i mængden af voksne copepoder senere på året.

En undersøgelse af de hydrografiske forhold i Isefjorden i de år, hvor der er foretaget indsamlinger (fig. 10—11), synes ikke at give nogen forklaring på variationerne i mængden af plankton.

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